Executive Summary for 2022 MITP Youngst@rs Workshop 'Rebuilding the Tower of Babel: Bringing Together the Various Languages of Color–Kinematics Duality'

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The 2022 MITP Youngst@rs Workshop on Color–Kinematics Duality (CKD) and the Double Copy (DC) was successfully held online from 11 April to 13 April 2022. The workshop presented a diverse range of perspectives on this topic, which concerns a surprising and hidden symmetry of gauge theories and its relation to gravity, with a wide gamut of applications ranging from the study of ultraviolet properties in supergravity to gravitational-wave astronomy.

Originally CKD/DC were discovered and studied using the techniques of scattering amplitude theory. However, recent days have seen a blooming of interest in alternative ways to understand this phenomenon, resulting in a 'Tower of Babel'-like situation with a number of competing formalisms. The purpose of this workshop was twofold: to allow researchers (especially the ones at the early stages of their career) to share and popularize their recent contributions to the field, and to find a common ground to set the goals the research community should pursue in the near term.

The approaches to CKD/DC presented in the workshop include, in addition to traditional scattering amplitude theory, approaches based on auxiliary spaces such as pure spinors, twistor spaces, and double/exceptional field theory; approaches based on homotopy (L_∞, C_∞) algebras; and approaches based on classical solutions. Furthermore, the workshop bore fruit in exploring various extensions to CKD/DC beyond the original examples of Yang–Mills theory, including massive theories, effective theories, (super)string theory, and beyond; as well as applications to precision gravity wave astronomy and black hole/black brane solutions.

Results The talks of Leron Borsten and Christian Saemann explore an action-based, homotopy-algebraic formulation of double copy. J. J. Carrasco and J. Roosmale Nepveu extend the reach of the CKD/DC paradigm to non-renormalizable effective field theories.

In search of new geometric formalisms, David Berman, Kara Farnsworth,

Alfredo Guevara, Max Guillen, and Silvia Nagy presented approaches to double copy based on the extended geometric spaces of twistors, pure spinors, and double/exceptional spacetime.

CKD/DC was originally discovered in the context of massless theories. Exploring whether the dualities hold when the theories are given mass has been an interesting direction that brings extra challenges. Mariana Carrillo, Callum Jones, Nathan Moynihan, and Shruti Paranjape attack this important problem from diverse directions and using different approaches.

The origins and perhaps the future of CKD/DC lie in string theory, where the KLT relations were originally discovered in the 1980s. Sebastian Mizera and Alexander Ochirov return to these themes to discuss manifestations of CKD in string scattering amplitudes.

Johannes Brödel and Hadleigh Frost discussed new CKD/DC properties of gauge theory scattering amplitudes.

Henrik Johansson discussed recent progress in the formulation of a kinematic Lie algebra for color–kinematic dual theory. Julio Parra-Martínez discussed a new geometry-kinematics duality relating the tree-level scattering amplitudes of all massless bosons and giving new soft theorem results.

Finally, Zvi Bern, one of the original discovers of CKD/DC, finished the workshop with an engaging and accessible talk on how CKD/DC have powerful applications to cutting-edge precision gravitational-wave astronomy.

Open questions   In general, the task of formulating appropriate language(s) for CKD/DC remains an open and urgent question. While the various talks in the workshop presented fascinating and intriguing bridges between the various formalisms, still the big picture remains dimly lit.

In particular, a suitable formalism should elucidate the structure and role of the kinematic algebra. It appears increasingly clear that homotopy-algebraic structures, in particular L_∞-algebras, play a key role here.

Another important open question concerns the major theme of the compatibility between CKD/DC and massive theories. The various talks discuss issues and constraints in the formulation of massive double copy. While much is now known, a more complete picture of the mechanisms involved in massive double copy remains elusive.